UNIVERSITY OF NORTH DAKOTA

ECONOMIC EXTRACTION AND RECOVERY OF REEs AND PRODUCTION OF CLEAN VALUE-ADDED PRODUCTS FROM LOW-RANK COAL FLY ASH

2018 U.S. Department of Energy National Energy Technology Laboratory Rare-Earth Element Annual Meeting, Pittsburgh, PA, April 10, 2018

DOE CONTRACT DE-FE0031490

EXECUTIVE SUMMARY

The overall proposed project goal is to demonstrate at the laboratory scale a novel, economically viable, and environmentally benign process for recovery and concentration of rare-earth elements (REEs) from low-rank coal (LRC) fly ash.

Overall technology objectives:

- Produce a domestic "green" source of REEs
- Recover other valuable minerals/elements from coal fly ash
- Remove toxic metals from the fly ash
- Convert the fly ash into a value-added product
- Generate selective REE extraction not typical with existing approaches for REE from coal fly ash

DOE CONTRACT DE-FE0031490

PROJECT TEAM

U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL)

- Anthony Zinn, Contracting Officer's Technical Representative
- Mary Anne Alvin, Rare-Earth Element Technology Manager

Technical Team

- University of North Dakota (UND) Energy & Environmental Research Center (EERC)
- UND Institute for Energy Studies (IES)
- Pacific Northwest National Laboratory (PNNL)

Partners

- Basin Electric Power Cooperative
- Southern Company Services
- Great River Energy
- North Dakota Industrial Commission Lignite Energy Council

PROJECT TASKS

Task 1 – Management Planning and Reporting

Perform overall project planning and management, and ensure all reporting requirements are met for the project.

Task 2 – Sample Procurement and Characterization

Coordinate sample procurement efforts with the project participants and power generation stations, and perform all standard analysis methods in accordance with the requirements of the project.

Task 3 – Laboratory-Scale Testing

Develop the procedures and techniques for concentrating the REEs in ash material to greater than 2 wt%.

Task 4 – Technical and Economic Analysis

Prepare a high-level technical and economic analysis with the goal to estimate preliminary capital and operating expenses, which will serve to direct future process development.

HEAVY REES (HREEs), LIGHT REES (LREEs), AND CRITICAL REES (CREEs)

- REEs are important elements used in high-technology products, such as catalysts, cell phones, hard drives, hybrid electric vehicle engines, lasers, magnets, medical devices, televisions, and other applications.
- LREEs are more abundant than HREEs; HREEs are more valuable.
- CREEs are those deemed as supply risk and highly important to the U.S. clean energy technologies going forward.

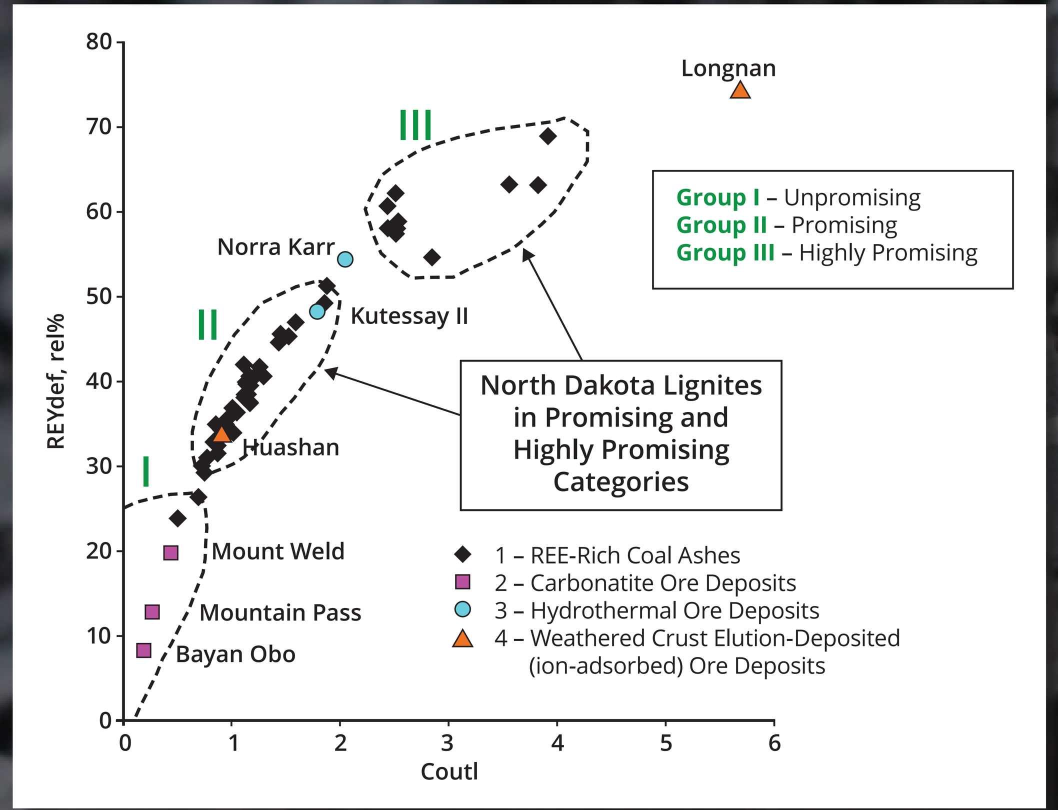
Element	Symbol	Atomic Number	Economic Class
LREEs			
Lanthanum	La	57	Uncritical
Cerium	Ce	58	Excessive
Praseodymium	Pr	59	Uncritical
Neodymium	Nd	60	Critical
Samarium	Sm	62	Uncritical
Europium	Eu	63	Critical
HREEs			
Gadolinium	Gd	64	Uncritical
Terbium	Tb	65	Critical
Dysprosium	Dy	66	Critical
Holmium	Ho	67	Excessive
Erbium	Er	68	Critical
Thulium	Tm	69	Excessive
Ytterbium	Yb	70	Excessive
Lutetium	Lu	71	Excessive
Yttrium	Y	39	Critical
Scandium	Sc	21	Critical

Most Critical REEs: Nd, Eu, Tb, Dy, Er, Y, Sc

Modified from Seredin, V.V.; Dai, S. Coal Deposits as Potential Alternative Sources for Lanthanides and Yttrium. *International Journal of Coal Geology* **2012**, *94*, 67–93.

APPROACH FOR REE EXTRACTION IN LRC ASH

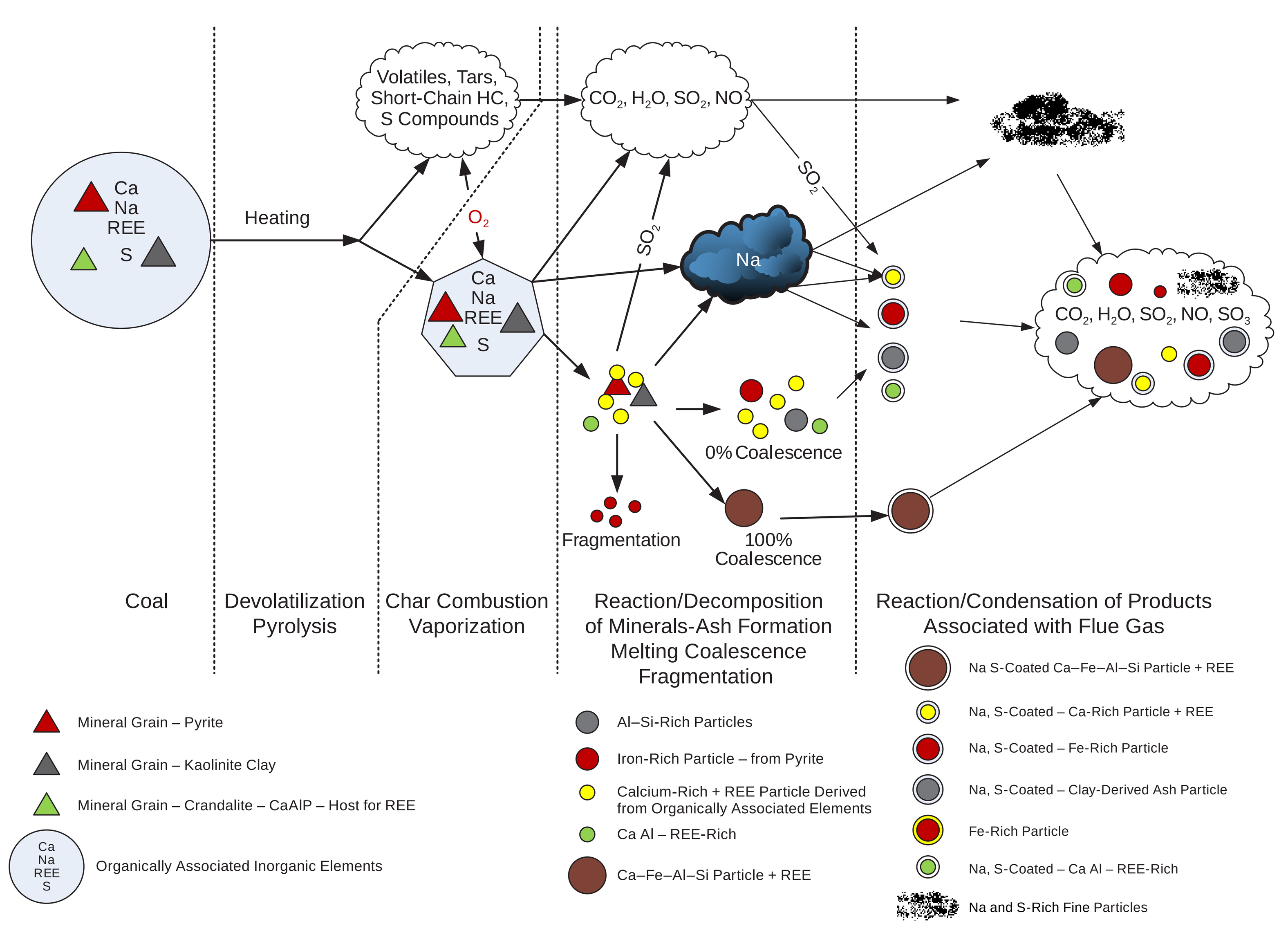
- Fly ash from coal combustion is particularly promising because of its enrichment in REEs (loss of diluting organic material results in ~10× concentration over coal) and also its presence in fine powder form, eliminating or reducing high-energy fine grinding typically required for REE processing.
- Apply the understanding of the transformation mechanisms in LRC of organically bound REEs for extraction.
- Develop a balanced approach of physical processing and chemical solvents for extraction.
- Use conventional, efficient recovery processes.



ASH FORMATION MECHANISMS IN LRC

- It is postulated that, for LRCs, the REEs will be associated with specific phases in the fly ash, and because of partitioning by size of these phases, selection of the fly ash from the appropriate zones of the ESP can generate a fly ash feedstock that is chemically more amenable to REE extraction.
- Amorphous glass phases in the ash will be particularly challenging, as its structure inhibits good access by traditional solvents. UND will utilize a unique method to transform a significant portion of the amorphous glass phase into a more suitable form for REE recovery, an approach that is made possible by the unique properties of LRCs.

ASH FORMATION MECHANISMS IN LRC



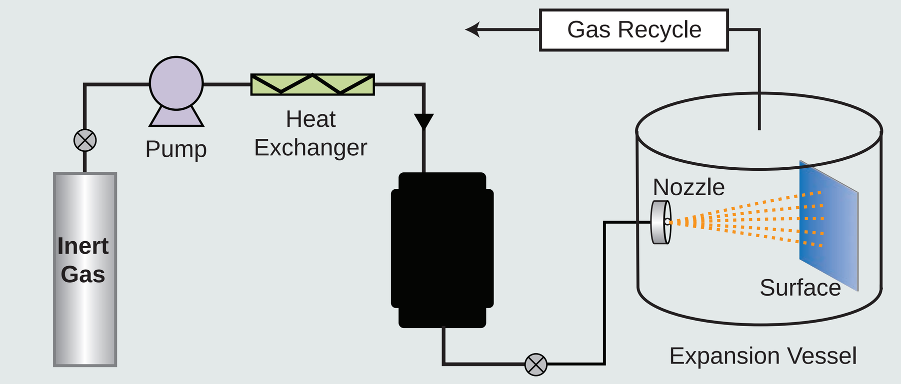
REE CONTENT OF FOUR PRB COAL ASHES MEASURED BY INDUCTIVELY COUPLED PLASMA–MASS SPECTROMETRY (ICP–MS)

(ppm, dry whole sample)

	Sc	Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Total REE
North Antelope	24.3	41	51.6	99.7	11.6	45.1	9.02	2.18	8.77	1.33	7.98	1.6	4.65	0.64	4.21	0.61	314
Antelope	21.8	49.8	65.1	123.4	14	53.4	10.7	2.59	10.6	1.6	9.51	1.92	5.49	0.76	4.88	0.71	376
Caballo	26.9	75.2	71	146.2	19	78.3	16.8	3.98	16.6	2.45	14.5	2.91	8.38	1.16	7.4	1.09	492
Black Thunder	30.7	82.5	86.9	176.2	22.3	89.2	18.7	4.6	18.3	2.7	16.1	3.1	8.9	1.2	7.8	1.2	570

CONVERT THE FLY ASH INTO A VALUE-ADDED PRODUCT

- Feasibility of using a rapid expansion process to create value-added particles from the residual ash material left over after extraction of the REEs.
- The goal is to produce a clean material with the porosity and particle size that will make it a value-added product salable to industry:
  - Zeolites
  - Sorbents
  - Polymers
  - Insulation
  - Cement



CONTACT INFORMATION

Energy & Environmental Research Center, University of North Dakota
15 North 23rd Street, Stop 9018, Grand Forks, ND 58202-9018

Bruce Folkedahl, Ph.D.
Senior Research Manager
701.777.5243
bfolkedahl@undeerc.org

www.undeerc.org